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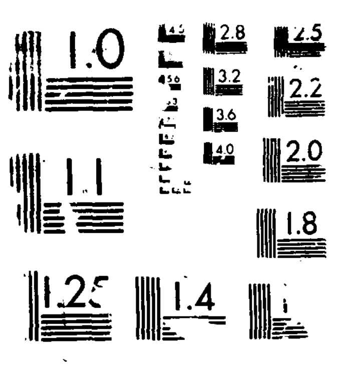
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A FRAMEWORK FOR FACILITY MODIFICATION

by

THOMAS GEORGE SYDELKO

B.S., SYRACUSE UNIVERSITY (1973)
M.S., UNIVERSITY OF WASHINGTON (1979)
M.B.A., BOSTON UNIVERSITY (1981)
M.P.A., WEBSTER UNIVERSITY (1985)

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Signature of Author Thomas G. Sydelko
Department of Civil Engineering
August 14, 1987

Certified by Jerome J. Connor
Professor Jerome J. Connor
Thesis Supervisor

Accepted by ____________________
Professor Ole S. Madsen
Chairman, Departmental Committee on Graduate Students

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Geographic Information System (GIS) technologies were utilized to manipulate, display and record data required for an example involving the modification of a U.S. Army direct fire training facility.

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A FRAMEWORK FOR FACILITY MODIFICATION

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THOMAS GEORGE SYDELKO

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ABSTRACT

A generic model for advising the facility modification process was developed. Object-oriented representations of the existing facility configuration, the new function(s) that it has been asked to accommodate plus facility design and operational constraints were constructed using hierarchical semantic networks. A facility-function matching process was used to identify conflicts and their causes. Cost data were combined with alternative evaluation algorithms and a heuristic search process to assist the designer/decision maker in both constraint relaxation and the selection of least cost conflict resolution strategies.

Geographic Information System (GIS) technologies were utilized to manipulate, display and record data required for an example involving the modification of a U.S. Army direct fire training facility.

Thesis Supervisor: Professor Jerome Connor

Title: Professor of Civil Engineering

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

In order to remain competitive in today's economic environment, organizations of all types and sizes are rapidly turning to the implementation of new technologies. The U.S Army is not an exception.

Modernization through the application of various mechanical, optical and electronic innovations has tremendous potential for increased productivity and efficiency. However, major obstacles exist that must be overcome. High tech solutions come with high dollar price tags. To justify the cost of using these innovations the potential economic efficiencies demonstrated under laboratory conditions must be realized after full scale production and implementation.

One major obstacle in the path of successful applications of new technology is the provision of adequate support facilities. Another is to properly train adequate numbers of operators, managers and maintenance personnel who are expected to achieve the higher levels of productivity and efficiency. Similarly, it is imperative that adequate stocks of operational materials and repair parts be readily available. If any of these obstacles are not overcome before a new technological advance is fielded the expected improvements that were used to justify the expenditures involved will not be fully realized.

Efficient communication is vital to the successful integration of new technologies into existing organizations.

Timely and effective communication of information, in every direction, allows all participants in the modernization process to keep abreast of the current status in new developments. Moreover, the potential impacts of decisions made regarding operational characteristics, physical dimensions and support requirements must be clearly communicated to the decision makers.

The unsuccessful introduction of new technologies into organizations can often be traced to the inability to clearly communicate the implied and explicit support requirements to those responsible for their provision. Similarly, once analyses of support requirements are completed they are too often not fully integrated into the higher level decision making process. The result is a new technological application that fails to achieve its expected potential.

Solving this problem for any particular organization requires a critical analysis of both the internal information flow process and the support requirement analysis procedures. The nature and magnitude of impacts on support facilities that are caused by alternative configurations of new technology applications must be understood by designers and top level mangagement. These impacts can not be properly evaluated and reported without clear communication of all relevant information regarding these possible alternatives. Conversely, the analysis must be performed quickly, accurately and the results communicated in a concise and easily understood format.

The same advances in technology that has created this problem offer possible solutions. Recent improvements in information processing, telecommunications and analytical methodologies can be combined to help realize the potential benefits from introducing new technologies into today's organizations (Mitra 86).

This thesis explores some of the problems involved with modernizing the U.S. Army. First is an analysis of the current process identifying critical shortcomings along with their causes. It will be shown that better planning and communication using improved tools, techniques and procedures are needed to enhance the likelihood of success for the Army's modernization program.

The major finding is that slow, inaccurate and incomplete analysis of necessary support facility requirements, particularly training ranges, combined with poor information transfer during the critical early phases of new equipment design leads to inefficient use of the Army's limited resouces. An additional finding is that inefficient identification and communication of support facility requirements lead to delays in providing adequate support and significant periods of reduced readiness.

To illustrate the concepts raised, this thesis closely examines the impacts of new weapon system technology on a particular type of training facility: the multi-purpose range complex (MPRC). Results from applying the Army's current force modernization process is contrasted to the outcome from the application of the proposed modified and proactive combination of new tools, techniques and methodologies.

The proposed procedures are designed to provide comprehensive and accurate training range requirement information to the initial system characteristic specification process plus, once these specifications are finalized, to provide advice to range designers seeking to satisfy all training standards at the least possible total cost while being mindful of both safety and environmntal considerations. This research and its final product fill two gaps in the present U.S. Army force moderization process. First, by facilitating the comprehensive and accurate impact analysis of firing range modification requirements, force modernization planners are able to make better long range decisions. Additionally, by allowing designers to more easily evaluate alternative range configurations the necessary modifications can now be made more quickly and at lower life-cycle cost.

The issue of facility modification and the principles incorporated in this research are not limited to military firing range applications. Altering existing structures to accommodate additional or different functions is a common design activity within both private and government organizations. As new construction sites with the most desireable characteristics become increasingly scarce and as the introduction of new technologies requiring structural and spatial modifications continues, the need for the design of rapid and efficient facility modifications will increase.

The procedures developed in this research can be applied to any type of facility. The techniques used for representation of a facility, its functions plus knowledge regarding the associated design and modification procedures are universally appropriate. The application developed within this thesis was selected to provide an example of the usefullness of the procedure. Other facility modification problems of this generic type may be analyzed and solved using these techniques.

The principle objective of this research was the development of a procedure to quickly and accurately identify, then assist in the selection of low cost solutions to, conflicts that occur when new functions are placed on an existing facility. To achieve this objective the research work plan included the construction of object oriented representations for descriptive, procedural and problem solving knowledge.

Since the identification of possible solutions to conflicts caused by the new functions is primarily a search problem, rules and heuristics used by designers were collected to improve the efficiency of this search process. A number of algorithmic procedures such as line of sight determination, projectile impact point calculation, and earthwork analysis were incorporated to provide designers with useful information.

To record and manipulate large amounts of terrain data involved in facility modification problems involving relatively large land areas, such as with MPRC's, computer based geographic information system (GIS) technology was incorporated. Interface procedures were developed to allow the designer the opportunity to relax previously specified constraints after the costs of correcting the conflicts caused by the constraint are provided.

There are four significant contributions from this research. First is the development of representation scheme for the descriptive, procedural and problem solving knowledge. Second is the methodology developed for identifying the conflicts caused by imposing new functions upon existing facilities. Third is the codification of the rules needed to efficiently prune the search process necessary to identify possible solutions. The fourth contribution is the integration of the first three into a computer implementation and case study as a proof of concept. Major portions of the first three contributions are accomplished within this thesis with completion of the first three and the fourth will be the focus of additional research in the form of a PhD thesis.

CHAPTER 2 ARMY TRAINING AND TRAINING FACILITIES

2.1 Objectives

The Army's three training objectives are to:

a. develop and maintain a motivated, discilplined, physically tough and well equipped force;

b. develop and maintain those individual and collective skills needed to deploy rapidly and successfully accomplish unit missions; and to

c. conserve training resources through increased use of training devices and simulation. (Army Regulation (AR) 350-1).

Firing ranges are essential to the Army's training process because they enable soldiers to become proficient with their weapon systems. Without this proficiency the Army would be unprepared for wartime missions. Ranges are dynamic systems comprised of people, equipment and land. They are designed to contain the weapon system during firing so that it does not affect the environment outside the target area.

To be effective, Army training must be performance oriented, demanding and realistic. Effective training with today's complex weapons and combined arms fighting doctrine require considerable resources. The increased leathality of modern weapons demands close attention to meeting personnel safety standards. Adverse environmental impacts are to be minimized. The Army's goal is to create no new contaminated land use areas (AR 210-20).

Variation between similar training facilities are kept to a minimum in order to gain the economies of standard designs. At the same time, multiple target scenerios must be presented to crews in order to avoid repititious and unrealistic training.

The principal objective of training managers is to provide safe and effective training for all assigned units at the lowest possible total cost (AR 350-1). To meet this objective requires not only efficient use of ranges in their existing configuration but the ability to analyze the impacts of changing technology and doctrine. Estimates need to be generated for the resulting increases in construction, operation and maintenance costs. An analysis of costs associated with alternative solutions is necessary for properly informed decisions to be made.

2.2 Training Difficulties

The trend of shrinking defense budgets leading to smaller and smaller amounts being allocated to fund training support facilities is the primary difficulty faced by today's training managers. Most of the remaining problems could be resolved given sufficient funding.

The dramatic increase in direct training costs (ammunition, fuel and personel) has lead to an emphasis on the development of training devices and simulators. The intent is to reduce the cost of training. However, this intent often adds to the requirements placed upon training managers with no offsetting increase in resources provided.

Some of these training devices, such as sub-caliber ammunition, cost significantly less but have entirely different firing characteristics that require modifications to existing training ranges. Since training with standard ammunition is never entirely eliminated, the result is an additional support requirement that must be accommodated.

Environmental restrictions on training are expected to continue to increase over time. Noise control will continue to be a major problem as populated areas grow closer to Army installations and their firing ranges. The high cost of land around these installations prohibits purchasing sufficient amounts of buffer zones.

2.3 Organizational Responsibilities

2.3.1 Department of the Army (DA)

The Deputy Chief of Staff for Operations (DCSOPS) provides policy and guidance for planning, programming, budgeting and funding of training ranges. The Deputy Chief of Staff for Personnel (DCSPER) is responsible for ensuring that unique range safety requirements are determined early in the development process for new weapon systems. It is also the DCSPER's responsibility to ensure that training ranges are designed, constructed and approved for use according to current range safety standards. The Deputy Chief of Staff for Research, Development and Acquisition (DCSRDA) is responsible for programming and budgeting the development and acquition of range instrumentation and targetry.

2.3.2 Chief of Engineers (COE)

The Chief of Engineers is responsible for developing standard designs for training ranges identified by the Directorate of Army Ammunition, Ranges and Training (DAART). The Corps' Huntsville (Alabama) Division has been designated as the Mandatory Center of Expertise regarding these standard designs. The Chief of Engineers must also provide Military Construction, Army (MCA) programming requirements for the timely construction of ranges and their modifications.

2.3.3 Training and Doctrine Command (TRADOC)

TRADOC is responsible for determining training objectives for all weapon systems plus providing alternative training strategies, range requirements and levels of proficiency to include those applicable to constrained training environments. TRADOC utilizes its subordinate branch schools to develop appropriate training objectives. For example, the Armor School at Fort Knox, Kentucky, produces all tank gunnery standards.

2.3.4 Directorate of Army Ammunition, Ranges and Training (DAART)

DAART acts as the Department of the Army's executive agent and presides over the Master Range Plan Prioritization Board (MRPPB). The MRPPB reviews all range construction and modification requests that have been submitted by the installations. After evaluation the board prepares a prioritized list of all range projects called the Army Master Range Plan which is submitted to DA.

2.3.5 Army Materiel Command (AMC)

AMC is responsible for identifying range requirements during development of new weapon systems in coordination with the Chief of Engineers and DAART.

2.3.6 Installation Commanders

Installations commanders must develop specific range construction and modification requirements to support all assigned training missions. Additionally, they must prepare and maintain a Five Year Range Development Plan to include construction, targetry, operations, maintenance and personnel requirements.

2.4 The Army Range Program and the Multi-Purpose Range Complex (MPRC)

2.4.1 The Army Range Program

The Army Range Program is controlled by DAART and designed to coordinate the standardization of training ranges. Standardization is intended to improve individual and unit capabilities throughout the Army regardless of a soldier's current unit. Standardization also increases soldier confidence by eliminating confusion and wasted time spent learning local modifications of basic tasks after each reassignment (Field Manual (FM) 25-1).

Personnel assigned to the Army Range Program provide guidance to the Corps of Engineers districts that support installation range requirements. Cost savings are achieved by eliminating the need to produce customized range designs from raw training standard and weapons characteristics data. Additionally, the time required to design, program and execute range construction or modification can be reduced significantly.

2.4.2 The Multi-Purpose Range Complex (MPRC)

The MPRC is the principal direct fire weapons training facility for the U.S. Army. Construction of MPRCs began in 1984 at Fort Hood, Texas, Fort Riley, Kansas and Fort Bliss, Texas. One or more MPRC is in place or presently approved for construction at each of the major continental United States army installation. Total construction costs for these MPRCs are expected to exceed $200 million. The generic design producted by the Huntsville Division is 1000 by 4600 meters in size and is intended to provide effective and cost efficient training for the Army's most modern equipment.

An MPRC is multi-purpose in three ways: multiple weapons can be used, multiple levels of training (individual, crew and collective) can be conducted, and multiple training scenerios can be programmed. This new type of facility has several significant advantages: it permits consolidated, specialized and individual training on one range; it maximizes land use; it reduces and consolidates construction costs; and it reduces hardware and maintenance costs. Most important of all this type of facility provides intensive and realistic training that challenges today's soldiers and modern weapon systems (FM 25-7).

Disadvantages of MPRC's center around their complexity and high demand for use. These facilities require careful design, construction and maintenance efforts in order to provide the desired level and quality of training. Because of their high cost, most installations will have only one MPRC. Demand for training is be high allowing only limited opportunities for routine maintenance and unscheduled repairs. The introduction of new weapon systems with different operational characteristics combined with changes in tactics and training requirements necessitates the ability to rapidly modify the facility when needed. An additional disadvantage is the that more intensive land use typically associated with MPRC training activities can have severe adverse impacts on land and natural resources.

An MPRC is composed of a roughly parallel maneuver lanes along which weapon systems move while attempting to observe fire upon and hit a variety of targets (figure 2.1). The targets are normally engaged as the weapon systems proceed down the center of the maneuver lanes. Firing from prepared defilade positions is periodically required the training scenerio. These defilade positions are shallow depressions just off the maneuver lanes that allow the weapon system to observe and fire on targets while minimizing the target size

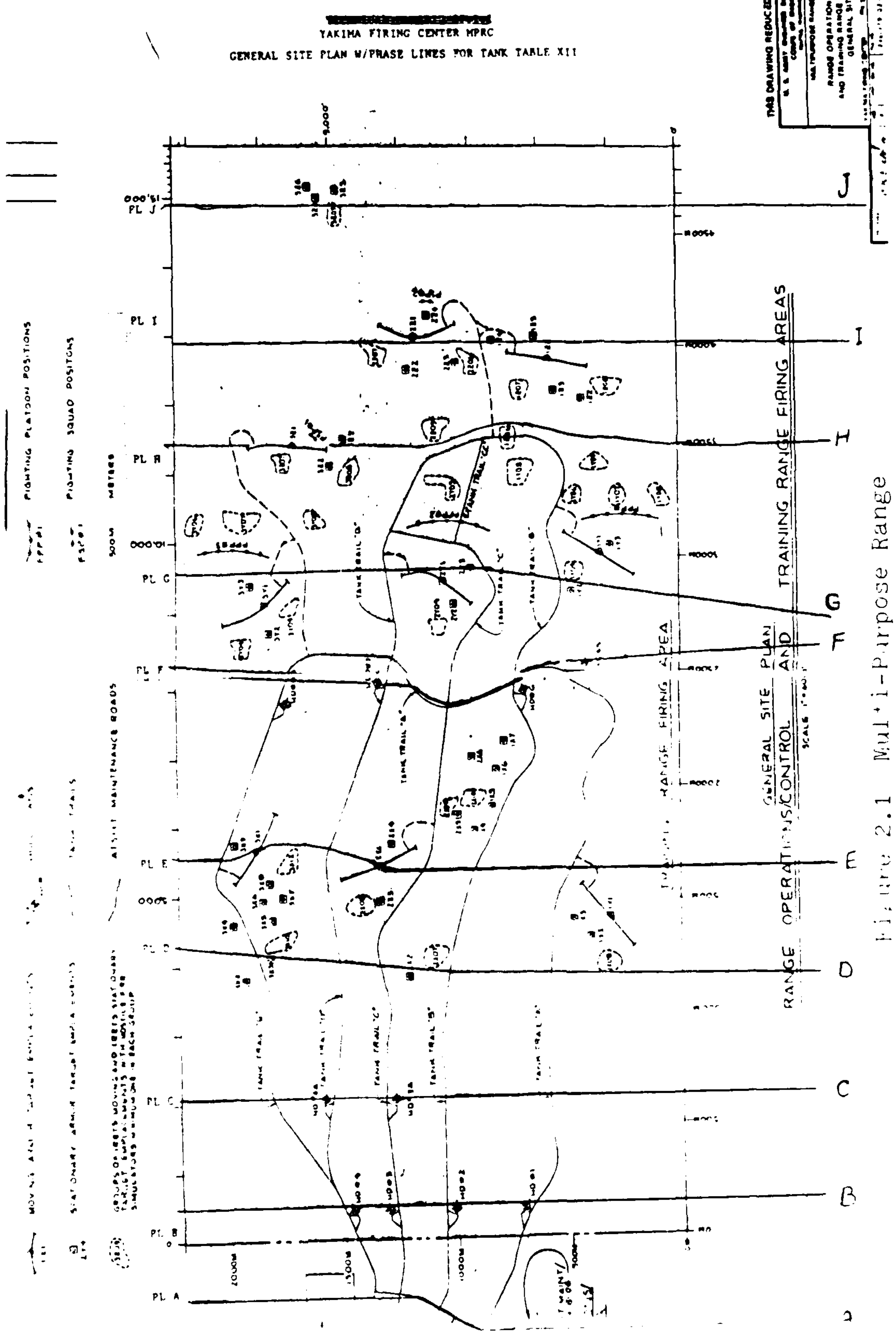

Figure 2.1 Multi-Purpose Range Complex Layout

that would be exposed to enemy gunners.

A standard MPRC includes 12 moving and 60 stationary vehicle plus 45 moving and over 150 stationary personnel targets. Moving targets are capable of being programmed to run at different speeds in order t offer a variety of exposure times. All targets can be equipped with heat sources and hostile fire simulators to allow engagement by thermal and night vision sights.

Targets are exposed to the moving or stationary vehicle crew by a computer program on a time driven basis. Hits are recorded electronically and an overall score is provided after each training sequence.

The major objectives governing MPRC target and firing point layout are to maximize target opportunities while minimizing both the range's surface danger zone and the earthwork necessary to achieve intervisibility or for protective berms (Huntsville Design Manual (HVDM) 1110-1-6).

2.5 Current MPRC Modification Process

At a few installations the original site layout of targets and firing positions is accomplished with the help of a digitized terrain model that is prepared by a private consulting firm under contract to the installation's supporting Corps of Engineers district office. Data from the terrain model and a CAD workstation are used by engineers to analyze the earthwork required an initial layout estimation. Changes are made in the layout based upon engineering judgement and experiance. The layout is finalized when the designers reach what they believe is a satisfactory solution. No optimization algorithms are applied to the procedure.

Intervisibility between targets and firing positions can be determined through the use of a program originally developed by the Corps' Waterways Experiment Station (WES). Training requirements (target type, distance and time of exposure) plus available target locations are formated for analysis by a personal computer based program. After the initial layout is provided to the district engineer it is given to an architect-engineer firm who develops the detailed design drawings and specifications necessary for range construction.

Training on the MPRC with equipment having modified weapons characteristics or under changed standards requires another intervisibility analysis using the modified input data. If no satisfactory target exposure sequences are found then the MPRC must be physically modified by adding new target locations or by providing additional firing positions. Presently there is no automated procedure available to assist in this process. The original digitized terrain model and the CAD workstation are used to generate possible modifications that must be checked by the separate intervisibility program.

2.6 Training Problems Caused by New Technologies

Army materiel developers strive to place the most sophisticated and effective equipment possible into the hands of today's soldiers. The improvements that they introduce are often the source of additional difficulties for training managers and their supporting engineers. Improvements in weapons technology and changes in doctrine frequently have significant impacts on the necessary training facilities. Materiel developers and tacticians are generally preoccupied with their primary goal of fielding a new weapon or gaining approval for a doctrine change. The job of anticipating, designing, programming and building adequate training facilities are much less glamorous but no less important to the Army's readiness.

New weapon systems often introduce new capabilities that require innovative training and modifications to existing facilities. The M1 tank introduced laser and thermal sighting and range finding as well as a stabilized main gun and turret. The M2 and M3 fighting vehicles introduced a stabilized 25mm chain gun. Future equipment, presently under various stages of development, will introduce still other new capabilities (Ludvigsen 87).

Improved capabilities of new system affect previous training doctrine and tactics which impact on the required training facilities. The M1's gas turbine engine allows exploitation of greatly improved acceleration and speed. Its greatly improved fire power (combined with its extremely high unit cost) caused the the number of tanks per platoon to drop from five to four.

Modifications to existing weapons systems can also impact on training support requirements. Improvements to muzzle velocities and maximum effective range are examples of such modifications to the M1's predecessor. Both changes required all existing ranges and their target exposure sequences to be analyzed to ensure safety standards would not be violated.

New technology introduces requirements for additional configurations of existing ranges much faster than older weapon systems are phased out. Moreover, training facilities such as MPRC's are frequently utilized by National Guard and Army Reserve units that are often outfitted with equipment passed down from active duty units.

The success of modern anti-armor missles has been proven in several recent conflicts around the world. The long held belief that the best defense against armored weapons was other armored weapons has been severly shaken. The cost effectiveness of these anti-armor weapons may easily cause a dramatic shift in the number and mix of weapon systems in the U.S. Army over the next few decades. Significantly different operational characteristics and employment doctrine will present additional challenges to both training managers and firing range designers (Barnaby 86).

Today's training facilities, particularly the MPRC's, will be called upon to accommodate an increasing variety of equipment and capabilities over their useful lives. In view of shrinking resources for funding range modifications, operations and maintenance it is important to develop procedures that can assist in the design of the necessary changes at the least possible cost.

CHAPTER 3 IMPACTS OF ARMY FORCE MODERNIZATION ON SUPPORT FACILITIES

3.1 Background

Force modernization within the U.S. Army has caused the introduction of many new technologies and has significantly improved the Army's potential capability to fight. In order to maximize the capabilities of new weapon systems adequate support facilities must be programmed, budgeted and built in a timely manner.

These increased capabilities have come at a very high cost. The majority of new weapon systems, including modern tanks and infantry fighting vehicles, have multi-million dollar price tags. Despite the trend toward reduced purchasing power of our defense budgets, rapidly rising personnel costs and tightening Congressional manpower ceilings, Army decision makers are determined to continue with their policy of high tech and high cost solutions for meeting real and perceived land based threats to U.S. security (Barnaby 86).

Army force moderization is a continuous process whereby the development and application of new technologies is pressed forward with a great sense of urgency. The intent is to achieve and maintain a decisive advantage over any potential battlefield opponent. The speed at which this development and fielding of new weapon systems plus improvements to existing systems may seem painfully slow in any one specialty area however Army wide nearly 500 new items will be introduced during the next ten years. Of these, approximately 50 will require significant changes in existing support facilites.

Supporting organizations within the Army are heavily burdened with the mission of providing timely and appropriate services and facilities for these new items. The challenge for supporting agencies is not unique to the Army or other branches of the armed forces. Private industry as well as non-military government agencies undergoing moderization programs are similarly challenged. Supporting the rapid introduction of new technology into any organization will always involve the quick and accurate analysis of changes in support requirements combined with the timely allocation of resources adequate to satisfy those requirements.

The Army's modernization program causes significant strain on its ability to provide adequate types and amounts of fuel, ammunition and repair parts to its units. Additionally, storage, maintenance and training facilities have often been found to be poorly suited to accommodate newly issued equipment or equipment modifications.

The inability to provide a smooth transition for new equipment introducted into the force structure has not been a result of ignorance or inattention. Force moderization is a high cost and high visibility program that has received considerable resources and attention from the highest Army officials. Difficulties in quickly and smoothly integrating a new weapon system into the force structure are setbacks that adversely impact on the Army's readiness as well as the careers of those responsible for that integration. The frequency and adverse impacts of these difficulties point out the importance of improving this process. Force modernization is a series of races. The primary race is against the time and funding constraints established for a new weapons system's development. The personnel participating in that race are the Program Manager (PM) assigned to the Army Materiel Command (AMC) and the civilian contractor developing the system to meet Army specifications. These participants must succeed in meeting performance and cost milestones to ensure continued Congressional funding. Throughout the conceptual design and early development stages a new system's operational characteristics are determined by a performance vs. cost compromise process. The point in time after which no addition compromises will be made is often poorly defined.

During this process a number of smaller races take place. These involve organizations responsible for providing the timely support services and facilities for the new systems. A new system's operational characteristics and physical dimensions are vital information to these organizations for determining the any new support requirements.

Ordnance personnel are concerned with meeting ammunition requirements. Force modernization often requires changes in existing contracts for production mix and capacities. Entirely new types or calibers of ammunition may need to be developed and tested.

The Quartermaster Corps and the General Services Administration become involved in a race to put in place the necessary contracts that will provide adequate repair parts once the new system is produced in quantity and issued to active duty units. They are also concerned with the actions necessary for obtaining and distributing the correct types and amounts of fuels and lubricants.

Each new item introduced causes the Corps of Engineers to become involved in a race to provide adequate storage, maintenance and training facilities. Although it is the specific responsibility of each installation commander to ensure adequate facilities are available to support all assigned missions, the Corps of Engineers is looked to for expertise in evaluating, designing, programming, budgeting and supervising the construction of any required new facilities or modifications.

The smooth introduction of a new weapons system requires that all of these smaller races be won. A delay in any one means that an entirely new system will not be fully operational on schedule. For a replacement weapons system the result would be that the old system could not be phased out until the support for the new system was judged to be adequate to maintain at least an equal state of readiness. Of course if the primary race for weapons development and production was delayed then any equal or shorter delays in providing adequate support would have no additional adverse impact.

3.2 Current Process, Shortcomings and Impacts

3.2.1 Current Process

The principal behind information exchange and decision making within the current Army modernization process is to designate one individual to be responsible for the development and fielding of each new weapon system. This individual is called the program manager (PM) and is assigned to the Army Materiel Command (AMC).

The PM's duties include coordination of the compromises necessary to balance the systems's desired operational, reliability, maintainability and physical characteristics within the authorized funding and time constraints for development and production. Direct costs for initial development and production are controlled through contracts with civilian companies. These expenses are closely monitored by the PM as well as by the Army Audit Agency and the General Accounting Office. The Congressional Budget Office also checks to ensure Congressionally approved funding limits are not exceeded.

Evaluating the indirect expenses associated with fielding a new system is also the PM's responsibility. These expenses are required to be routinely integrated into the decision making process. The formal mechanism that assembles the necessary information is Army Regulation (AR) 710-127 that calls for an integrated logistics support (ILS) plan to be prepared for each new system. The ILS plan is designed to ensure appropriate levels of support are put in place prior to fielding new systems. AR 710-127 also requires the formation of an integrated logistics support management team. The ILS management team consists of representatives from OCE and TRADOC plus DCSPER and DCSLOG. These representatives provide the PM with advice on engineering, training, personnel and logistic support matters, respectively.

For selected major systems, a significant portion of an ILS plan is the Support Facility Annex (SFA) which is prepared by the OCE's Directorate of Engineering and Construction. The SFA is an analysis of the requirements created by the development and fielding of a new weapons system.

After assembling all available and relevant information regarding the direct and indirect costs of each feasible alternative system configuration, the PM coordinates the decision making process that finalizes the new system's design specifications and characteristics. These are used as guidelines by the various Army organizations that provides the necessary support as mentioned earlier: ammunition and repair parts plus storage, maintenance and training facilities.

Designing adequate support facilities for each installation requires information on exactly what types of new equipment that are under development will be issued along with projected quantities and timing. OCE's district engineer offices assisting installation commanders in this process are aided by several publications. The Army Stationing and Installation Plan (ASIP) contains listings of which units are currently assigned to each installation plus any projected changes. Tables of Organization and Equipment (TOEs) specify the number and types of equipment each unit is authorized. Periodically new item distribution plans are published to announce the schedule for new equipment to be fielded along with which items are being replaced. Finally, Army Moderization Information Memorandums (AMIMs) are published listing characteristics and status of equipment currently under development.

From these sources each installation is expected to calculate support requirements, initiate designs and program necessary new construction or modifications in time to accommodate the arrival of the new equipment.

3.2.2 Shortcomings, Causes and Impacts

A particularly important shortcoming in the current force modernization process is the natural bias of PMs toward development and production problems at the expense of system support issues.[1] Cost overruns, missed developmental milestones and poor system performance during operational

[1] Greggory Ciotti, private interview held during visit to the Office of the Chief of Engineers, Directorate of Engineering and Construction, Moderization Branch, Washington, D.C., April 1987.

testing are real-time problems for the PM. An all too human reaction is to allocate a majority of available effort to ensuring these high visibility and objective aspects proceed smoothly. The cost of support facilities are quite small in comparison to most modern weapon system development and production costs. However, poorly timed or inadequate facilities, particularly training ranges, can easily negate a large part of the potential improvements in effectiveness over the system being replaced.

The current process encourages PMs to focus on near term issues that can adversely affect their personal performance ratings. Additionally, assignments for the active duty officers in these positions are not for the duration of the project. Long development cycles combined with the typical three year assignments as a PM accentuate this tendency. The present process has few incentives for PM's to be concerned with such subjective issues as the quality of support facilities that will be needed in the distant future.[2] The need is clear for those responsible for designing and building these facilities to conduct detailed analyses and provide a bottom to top flow of information in a format that can be easily incorporated by the P.M. into the decision making process.

A review of the current information transfer process

[2] Frank Clifton, private interview held during visit to the Office of the Chief of Engineers, Directorate of Engineering and Construction, Moderization Brarch, Washington, D.C., April 1987.

reveals another serious shortcoming. No truely automated and comprehensive sourse of relevant information exists. Numerous pieces of important data must be gleaned from a varitey of manual reports and documents. Recent efforts to provide automated assistance using the Corps of Engineers Programming, Administration and Execution (PAX) system have somewhat impoved the availability of information and allowed planners access to a small number of analysis packages.

Under the present process a support facility annex to the ILS plan is only prepared for the largest new developments. The large amount of resources necessary for these analyses prevent their preparation on a more routine basis. Furthermore, the considerable amount of time required to complete an SFA can also lead to important developmental decisions being made with incomplete or missing results.

Different sources of funding is the cause behind another significant shortcoming. The current process is designed to develop and test a new weapon system at the lowest possible cost and to produce as many units as possible within the Congressionally authorized funding. The cost of necessary support facilities such as modifications to training ranges is paid through MCA dollars and is normally justified by the previous appropriation for a new system's development and production. Total system funding requirements are seldom combined for a single appropriation. The impact is that installation commanders are uncertain as to the amount of money that will be available for building these ranges. This uncertainty has caused problems in designing the facilities and initiating the long MCA request cycle.

Minimizing the costs of new or modified training ranges requires that the supported system's characteristics be specified with an understanding of the impacts resulting from each of the possible configurations. Similarly, operation and maintenance (O&M) costs can be minimized only through an analysis of alternative training scenerios specified by TRADOC and DAART.

Presently, training objectives and standards are established with little or no consideration of the resulting O&M implications.[3] DAART and the OCE's Huntsville Division produce standard training range designs that can be modified slightly as necessary to adapt to an individual installation's available terrain. These ideal case designs have considerable potential for improvement through the use of a process that would seek to achieve the least total cost of construction, operation and maintenance.

The current slow analysis process and a lack of visualization make practical evaluation of multiple alternatives a very difficult task. The result is an incomplete analysis with less than adequate consideration of support facility requirements during the development process.

In summary, the present force modernization program puts

[3] Howard Blood, telephone interview held with the project manager for the Army Range Program, Huntsville, Alabama, April 1987.

installation commanders and their supporting engineers in a purely reactive position regarding their ability to provide adequate support facilities for new equipment. Little input from their perspective is presented to the decision makers during the critical phases of both the equipment and the training standards development process. This causes an inefficient expenditure of already limited resources.

3.3 Recommended Improvements

3.3.1 Objective

The objective of these recommended improvements is to generally increase the efficiency of the Army's force modernization program and to develop a generic methodology that can advise the facility modification process. As stated earlier, a smooth introduction of new technologies is necessary to realize their full potential for increasing the Army's readiness. All pieces of the modernization process including adequate support facilities such as training ranges must be brought together in a timely and efficient manner for the program to be successful.

This improved efficiency can be obtained by providing timely and accurate information concerning the impacts of decisions made regarding weapon systems characteristics and training standards. Additionally, once these variables are specified, the efficiency can be further improved by assisting design engineers in their efforts to satisfy given training standards while matching weapon fire and maneuver characteristic to the available training land.

Adaptation of existing multi-purpose range complexes provides an excellent application where the proposed improved process can be demonstrated. These range complexes, which are intended to accommodate a wide variety of weapon systems over many years, will require numerous modifications over time as new generations of weapon systems with improved capabilities based on new technologies are fielded.

3.3.2 Required Process Changes

Changes are necessary in several levels of the current process. First of all, separate appropriations for new system development, production and support facilities must be eliminated. The total cost of adding a new or replacing an existing capability must be calculated and approved as a complete package. This would dramatically shorten the present MCA cycle time and prevent the fielding of new systems years before adequate support facilities are built or necessary modifications to existing facilities are made. Separate funding to explore the feasability of a new technology is still appropriate however the present piecemeal approach is a major source of today's inefficiency.

Secondly, the total cost for a new system must include a detailed analysis of expected operation and maintenance expenses. The magnitude of these expenses need to be fully evaluated and presented during the appropriation hearings in Congress. Without this modification inappropriate decisions are indirectly encouraged whereby development and production costs are kept down at the expense of higher and separately funded O&M costs.

The techniques presently utilized to produce the necessary information must be updated. Modern computer based methodologies are capable of producing fast, quantitative analyses of multiple alternatives. These capabilities need to be implemented in place of the primarily manual procedures now being used to produce support facility annexes. Recent innovations and improvements in data processing and information transfer techniques also need to be incorporated. The huge amount of data that must be stored, retrieved and manipulated can now be more efficiently handled using currently available hardware. Information from completed analyses must be transmitted quickly and in an appropriate format to be properly integrated into the decision making process.

New tools such as geographic information systems should incorporated into the process for terrain intensive facilities. These systems add high speed data analysis and visual analysis capabilities. Weapon firing characteristics, required safety zones, environmentally sensitive areas and vehicle trafficability information can now be graphically depicted to highlight firing and maneuver constraints that exist on available terrain.

Another change concerns the authority of the ILS management team. The present team composition adequately represents the issues related to support facilities needed to keep pace with the force modernization program. However, the team's current advisory role limits its effectiveness. Under the present process, development and production decisions that result in mismatched or inadequate support facilities can be made over the objections of the ILS management team. A better balance of power between the PM and this team must be established.

These major changes and process modernization efforts are necessary to improve the Army's present force modernization process and to provide for a more efficient utilization of available resources.

CHAPTER 4 A FRAMEWORK FOR ADVISING WEAPON SYSTEM DESIGN AND TRAINING RANGE MODIFICATION

4.1 Problem Definition

Slow, incomplete impact analysis plus poor information transfer and ineffective organizational design often are the cause of improper decisions regarding many aspects of facility modification. The implementation of new technologies offers possibilities of improved efficiencies however caution must be exercised to prevent adverse impacts or improper preparation from offsetting those benefits. Unless designers are provided timely and comprehensive evaluations of the alternatives under consideration they are severely limited in the ultimate quality of their decisions (Mitra 86).

Within the U.S. Army, force modernization is a necessary and important process. It is also an extremely expensive process that must be wisely managed. Many complex tasks must be accomplished under a highly coordinated schedule. Failure to properly incorporate all impacts into the early weapon development process or failure to provide adequate support facilities are problems that have reduced the overall effectiveness of Army force modernization.[1]

Training facilities, particularly firing ranges such as the multi-purpose range complex, are among the most critical

[1] Frank Clifton, private interview held during visit to the Office of the Chief of Engineers, Directorate of Engineering and Construction, Moderization Branch, Washington, D.C., April 1987.

classes of support facilities. The quality of these ranges is a major factor in how well a new weapon system performs its primary objective: to improve the overall readiness of the Army.

One significant capability that is missing from the force modernization process is the ability to provide input to designers and decision makers from the training managers' perspective. This ability is necessary to advise the project manager establishing system specifications plus the TRADOC representatives establishing training objectives and standards. The purpose of the advice would be to help achieve the system's performance objectives at the least possible cost of building new or modifying existing training facilities.

Since many conflicting factors must be included in both the P.M.'s and TRADOC's decision making process, the final system configuration and training doctrine will undoubtedly be sub-optimal from the least cost impact on training facilities point of view. The same framework for providing the initial advice on weapon system configuration would also be capable of providing designers with advice on minimizing training facility modification costs once the finalized system specifications and training doctrine are published.

The design of the framework for such a weapon system design and training range modification advisor is the objective of this research.

4.2 Solution Requirements

Improving the facility modification process requires a thorough understanding of the process objectives, information needs plus the tools and procedures available for providing possible solutions. This understanding allows the alternative solutions to be evaluated and the most appropriate selected for further development and implementation.

The primary objective of this facility modification framework is to help correct a significant deficiency in the Army force modernization process. Presently, specifications and performance criteria as well as training standards and criteria for new weapon systems are developed without proper consideration of impacts on support facility requirements.[2] The five major process changes that must take place in order to properly address this important issue were outlined in section 3.3.2. One change (combining weapons development production and support facility appropriations) will require Congressional action. Another change (increasing the authority of the ILS management team relative to the project manager) can be accomplished through Department of the Army directive and modification of the appropriate regulations.

The remaining recommended changes require a significant modification in the manner that information is represented, analyzed and then presented to designers and decision makers

[2] Ibid.

involved in both weapons development and training doctrine. When operational, this framework will improve the overall effectiveness and efficiency of the force modernization program.

The second objective of this framework is to assist training range designers once new weapon system performance and training doctrine have been established. Similar information requirements and knowledge representation techniques can be utilized to accomplish both objectives.

An important goal of the improved process is the ability to estimate costs associated with support facility impacts that result from various weapon system configurations and capabilities as well as alternative training standards. These cost estimates must be produced after satisfying environmental and safety constraints (Riggins 87). New estimates must be rapidly produced to facilitate sensitivity analysis.

The capability to recommend least cost firing range layouts is essential once the numerous system characteristics and training standards are finalized. From a training realism and range operation perspective, a highly desireable feature would be the capability to generate a variety of firing scenerios and to link these to the ranges' target control and scoring computers.

4.3 Applicable Technologies and Methodologies

4.3.1 Knowledge Representation

4.3.1.1 Representation Methods

Effective and efficient problem solving requires the selection of a suitable representation technique to describe the available knowledge. Two important factors in selecting an appropriate technique are the expressive power of the representation and the computational efficiency. Expressive power is a function of the ease with which the knowledge can be described and read. Computational efficiency is a measure of the run - time performance overhead in processing the representation used. At one extreme, a highly expressive representation might employ a natural language to describe the knowledge while at the other extreme, a representation based on a programming language might be used to ensure rapid execution. In general, the technique selected is a compromise that is sufficiently understandable to facilitate knowledge base maintenance and improvements while providing an acceptable speed of execution (Kowalski 86).

Frequently used knowledge representation techniques include the use of rules, semantic networks, frames and objects. Rules are the most common form of representation. Each rule consists of one or more conditions which, if satisfied, lead to one or more actions (see figure 4.1). Knowledge bases using rules have the advantage of being easy to change since each rule is a declarative statement of

IF THE ANIMAL IS A BIRD

AND IS A CANARY

THEN ITS COLOR IS YELLOW

FIGURE 4.1 KNOWLEDGE REPRRESENTATION USING RULES knowledge which is isolated from all other rules. Rules also seem to match the way humans formulate knowledge in a cause and effect manner. Problems can develop when the knowledge base exceeds a few hundred rules since it becomes difficult to determine how changes in individual rules affect the overall problem solving process. One method to minimize this problem is to divide the knowledge base into groups of rules where each group addresses a different aspect of the problem Shirai 82).

Semantic networks represent knowledge in the form of a network of relationships. The network consists of a series of nodes interconnected by arcs (see figure 4.2). The nodes represent the elements of the knowledge while the arcs determine the relationship between nodes. There may be inheritance relationships where one node inherits the properties of the other node or a descriptive relationship in which one node describes the properties of the other. A problem with semantic network representations is the difficulty of updating them to reflect new knowledge or changes in relationships (Winston 84).

Frames combine the concepts of semantic networks and rules. A frame is a template of a number of slots and the values that the slots can take (see figure 4.3). These values can be in the form of rules where a dedductive process is necessary to derive the value of the slot. Frames have the advantage of explicitly representing knowledge relationships in hierarchial form so that lower frames in the

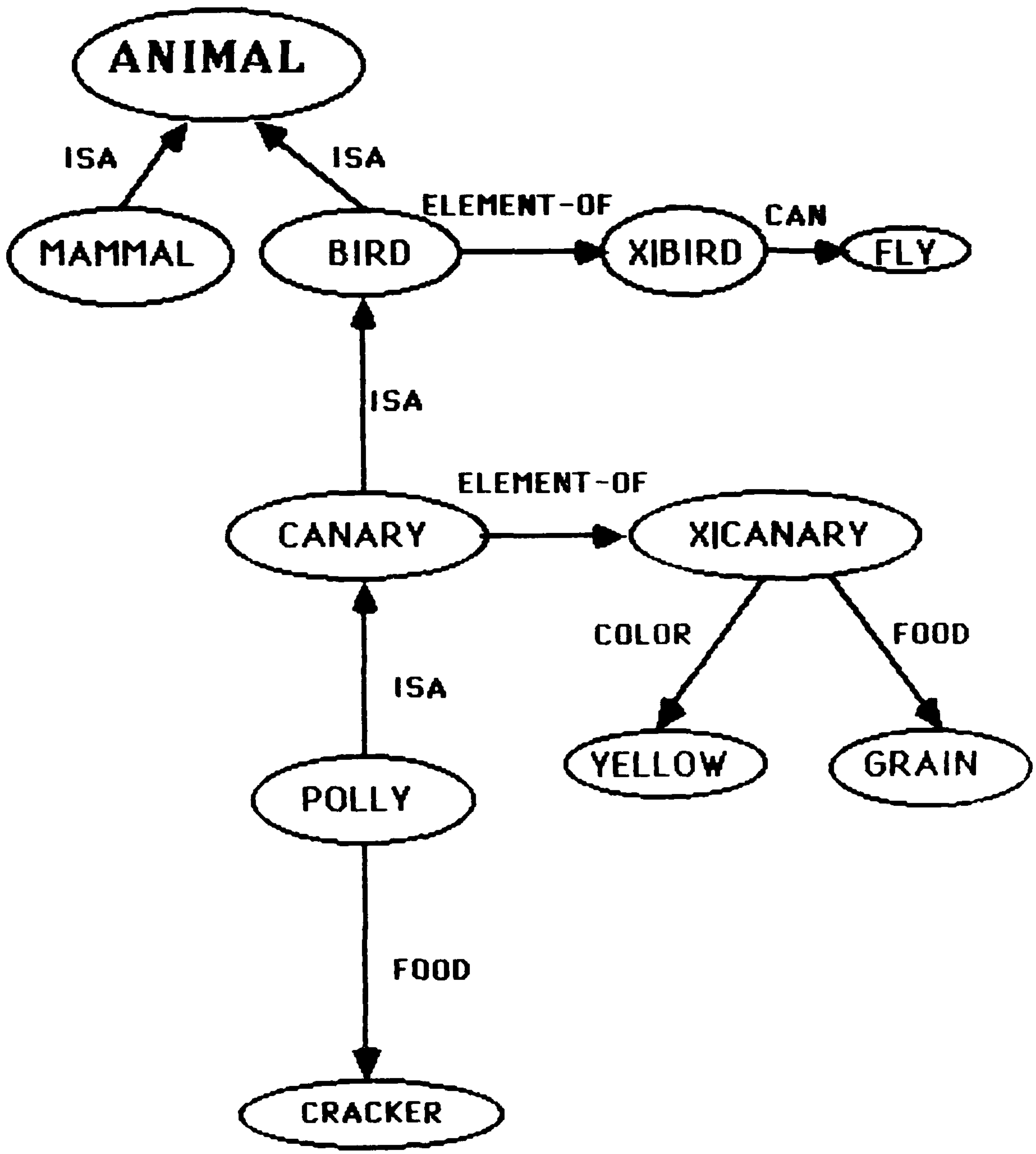

FIGURE 4.2 KNOWLEDGE REPRESENTATION USING HIERARCHICAL SEMANTIC NETWORKS

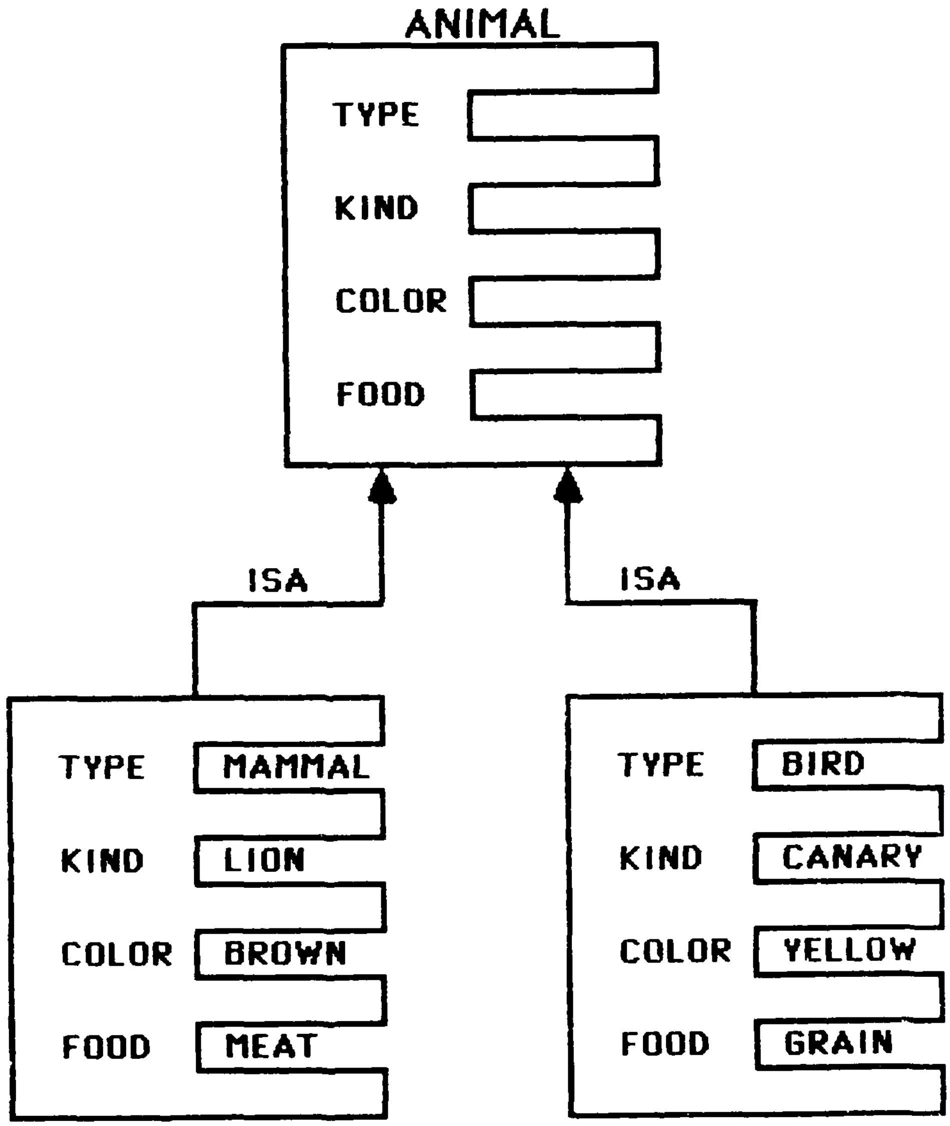

FIGURE 4.3 KNOWLEDGE REPRESENTATION USING FRAMES

hierarchy can inherit values from higher frames.

Objects use a representation similar to frames and incorporate the concepts of slots, values and inheritance. The key difference is that communication with objects is in the form of messages which result in objects being used as agents to perform tasks requested by other objects via these messages (see figure 4.4). An object can represent a group of rules with messages used to schedule the execution of the rules. Each object has distinct properties associated with it and is situated within a network hierarchy that lets it inherit properties of higher level objects. When an object receives a message it consults its data base and rules to decide what action to take. The rules may be stored with the object or in a higher level object somewhere else in the network. In most cases the action involves sending new messages to other objects in the system.

4.3.1.2 Types of Knowledge

Knowledge needed in the facility modification process can be classified according to the manner in which it is utilized. Three distinct types of knowledge are necessary within this framework: descriptive, operative, and problem solving (Partridge 86).

Descriptive knowledge is needed to define the problem domain. For this particular facility modification application concerning the MPRC, data describing several system components are needed. These include but are not limited to the physical composition of the existing facility,

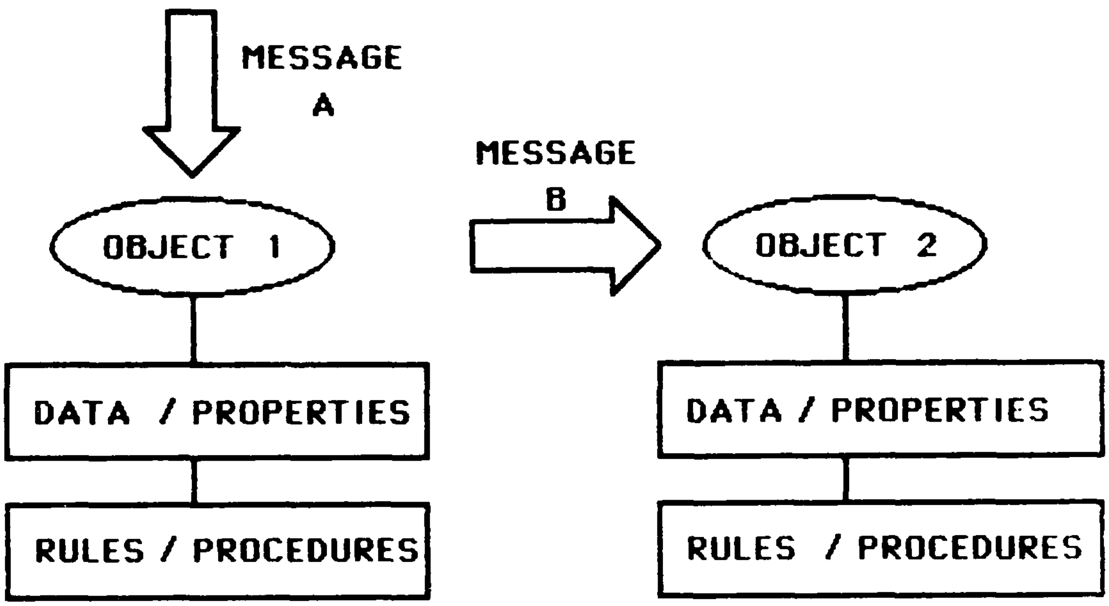

FIGURE 4.4 KNOWLEDGE REPRESENTATION USING OBJECTS

the functions that the facility is asked to perform, the constraints concerning facility design and operation, plus rules and heuristics used to guide the facility modification process.

Operative knowledge consists of various algorithmic operations that are used to manipulate portions of the descriptive knowledge in order to proceed toward the problem solution. For this application, these algorithms include target to firing point intervisibility determination, projectile impact point calculation, excavation estimation and cost analysis.

Problem solving knowledge includes rules, heuristics and laws governing the modification process and control of that process. It also includes what is termed metaknowledge. Metaknowledge is knowledge about effective strategies and procedures for using the domain knowledge - in effect, knowledge about knowledge. The facility modification framework involves the problem solving knowledge being used to select the appropriate timing and sequence for operative knowledge to act upon the descriptive knowledge.

4.3.2 Geographical Information Systems and GRASS

A geographical information system (GIS) organizes, manages, manipulates and displays geographical data. Virtually any form of data related to the landscape can be included such as soils, slopes, land cover, roads, pipelines, cemetaries, and political boundaries. Common data sources

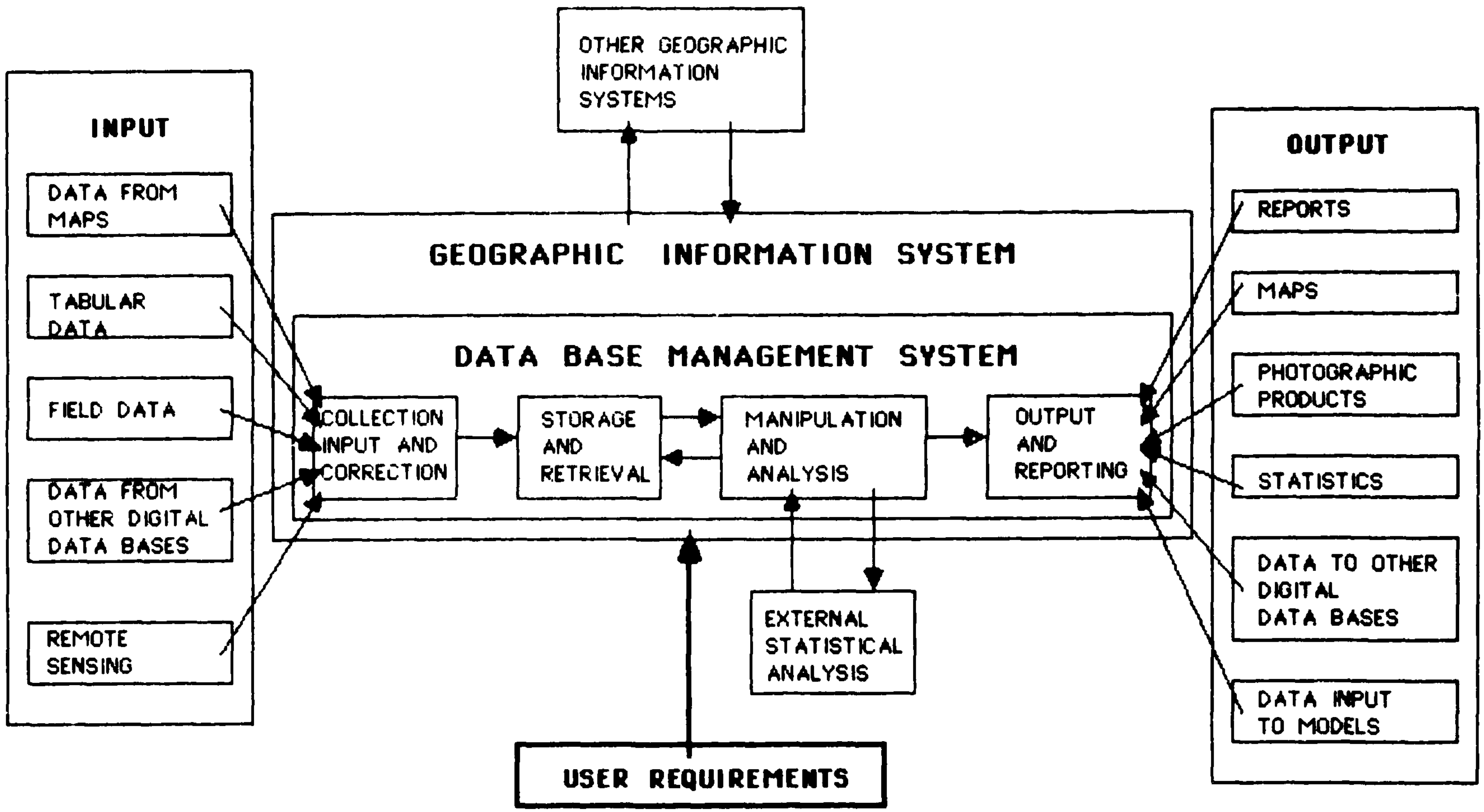

FIGURE 4.5 GEOGRAPHIC INFORMATION SYSTEM COMPONENTS AND FUNCTIONS

include soil survey maps, imagery from satellites, topographic maps and special land use planning reports (see figure 4.5).

Within a GIS, information is stored in map layers with each layer representing some set of naturarl or cultural landscape features. Each map layer is stored as a grid and individual grid cells are assigned a class value. For each data type such as soil, elevation or slope steepness, there is a separate map layer that is divided into several classes such as soil type, and degree of slope steepness.

A computer based GIS is useful in the modification process for facilities similar to an MPRC because of the large amount of terrain information involved plus the ability to rapidly display a wide variety of facility related data in an understandable and graphic format. A GIS allows photographic imagery to be compared to other map layers such as elevation contours, watershed boundaries plus MPRC maneuver lanes and targets. It also allows specific areas to be enlarged, new maps to be created and analyses to be conducted.

All map layers have associated tables that provide statistics on the number and percent of cells (land area) in each class as well as background information about the data sources and class divisions. Map layers of particular use for the modification of MPRCs are water boundaries, streams, soils, roadways, urban areas, landcover, archeological and historical sites, watersheds, vegetation, forest areas, grading contours, elevations and drainage. This information can be obtained from field studies, natural resource maps, military installation maps and topographic maps.

To complement GIS technology, the United States Army Construction Engineering Research Laboratory (USA-CERL) has developed an integrated image processing/geographic information system called the Geographic Resources Analysis Support System (GRASS). This system is a comprehensive set of computer based tools to display, analyze and manipulate maps, images and associated data. GRASS has three subsystems:

1. GRID: Tools for overlaying, analyzing and displaying grid cell databases. Maps generated can be printed in full color and at any scale on an inkjet printer.

2. IMAGERY: A highly graphic and interactive image processing package that generates GRASS-grid data layers based on LANDSAT, high altitude photographs and various other image sources.

3. MAPDEV: Tools for generating GRASS-grid format and United States Geodedic Survey Digital Line Graph (USGS-DLG) format files. Capabilities are provided for reading data from outside sources as well as producing data from a digitizer. Capabilities are also provided for reading and processing Digital Elevation Model (DEM) data to produce elevation, slope, aspect, stream and watershed data in GRASS-grid format.

GRASS has been used on military installations to site landfills, identify potential archeological sites on unsurveyed lands, inventory timber and wildlife resources, identify landscape changes associated with training and to perform analysis for environmental impact assessments.

Instead of shuffling through stacks of maps and images of various scales and sizes, GRASS users can rapidly locate, display, edit, label and print out maps at any selected scale, overlaying coordinate grids and any combination of line drawings (vector files). Reports providing full sets of area statistics can be generated quickly. Users can perform area and length calculations interactively using graphic monitors, accomplish photo interpretation tasks using screen digitizing, and display maps in three dimensional relief.

Additional GRASS functions include the ability to perform proximity, neighborhood and expert system rule based analyses plus weighted overlays and boolean combinations. Other GRASS tools facilitate statistical analysis of site locations, generate coincident tabulations and reclassify existing map layers. The graphic and interactive capabilities of the image processing tools allow users to extract raw image data from tape, statistically manipulate imagery to create new interpretations and geographically rectify images to match a set of maps. The ability of the GRASS computer to rapidly repeat analyses with new parameters and rules, possibly adding new or different data, allows users to consider several different options thereby improving the quality of the decisions made.

4.4 Proposed Framework

The generalized facility modification process framework begins with the identification and representation of descriptive knowledge for both the facility itself and the new function or functions that the facility is being asked to accommodate. This knowledge utilizes the hierarchial semantic network technique as described in section 4.3.1.1. Knowledge regarding the physical, safety and environmental constraints governing the design and operation of the facility must also be collected. These constraints are expressed in the form of rules.

The descriptive knowledge and constraints are combined in a function matching process that employs object oriented programming techniques to identify the conflicts that exist. The user is given the opportunity to relax constraints that have been determined to be the cause of one or more facility-function conflict.

Each constraint previously identified can be classified as being either hard or soft in nature. Hard constraints are such that they may not be violated in the course of facility operation or modification. Soft constraints are those that may be partially or completely relaxed if the designer or decision maker so desires and has the appropriate level of authority. These soft constraints are similar to design or operational goals in that they need not be completely satisfied but are highly desireable.

Facility modification rules and heuristics are also gathered in order to efficiently guide a search process that is designed to identify possible conflict resolution strategies. Necessary cost information concerning these resolution procedures is called up from the system's data base to provide estimates to the user.

For the higher level planning uses of this methodology, the output is used to identify the nature and general magnitude of the facility modifications dictated by the various alternatives under consideration. When the impacts on several similar facilities are needed, the evaluation process is repeated after the substitution of relevant site specific data for each individual facility involved.

For the design of specific modifications to an individual facility, the methodology assists the user in the design process by providing a detailed evaluation of each possible conflict resolution strategy.

4.5 Information Requirements

4.5.1 Existing Facility Descriptive Knowledge

An essential component of the descriptive knowledge for land based facilities such as the multi-purpose range complex is the digitized terrain model recorded in a geographic information system format. This terrain model facilitates the recall and manipulation of elevation and contour data for such operative knowledge algorithms as line of sight determination and earthwork volume estimation.

Firing ranges are primarily comprised of a series of firing points and target locations. Firing positions on

MPRCs begin at the baseline or starting point of the maneuver lanes and are defined by centerline and elevation data for the length of each lane. Occasional defilade or off-lane firing positions are provided for each lane and are defined by their grid coordinates and elevation.

Target data for an MPRC include the target type (armored vehicle, non-armored vehicle or personnel) plus location and elevation information. Moving targets must include their possible speeds as well as target start and stop point information. Elevation and position data for all points along the path of moving targets can be calculated using data from the digitized terrain model. Additional descriptive knowledge include the boundaries of the current range impact area and surface danger zone.

Various cost data are necessary to calculate estimated expenses of alternative solutions to the training conflicts identified. Among these are unit costs for line of sight excavation, protective berm construction and maneuver lane modification. Costs for the installation or relocation of targets plus construction of new defilade firing positions are also needed. Additionally, range operation and maintenance costs (both fixed and variable) are required as is an estimate of the cost to transport units to another installation as an alternative to modifying the existing facility.

4.5.2 Training Requirement Knowledge

For each new training function that a facility such as the MPRC is asked to accommodate, there exists a data set that fully describes the requirement. Prior to describing the actual fire and maneuver scenerio, information concerning the number and type of weapon systems involved in the training is needed. Among the weapon system data needed is the type and models to be used plus gun tube heights, ammunition types to be used and the appropriate firing ballistics tables.

The training requirements are formally stated in a gun-target exposure sequence. This sequence defines a series of training tasks that include the types, distances to, and exposure times of various targets that will be presented to the weapon system crew. A group of six to ten different gun-target exposure sequences each with eight to fifteen tasks are used to satisy periodic crew qualifiacation requirements.

Each gun-target exposure or task is described in terms of firing point and target data. Necessary firing point data includes, for stationary positions, whether the firing position must be from defilade or from the maneuver lane. For moving firing positions the required vehicle speed is required.

Necessary target data include the target type and if it is to be moving or stationary. For moving targets, the required speed is needed. Target exposure time and required distance form the weapon system are also needed.

4.5.3 Constraint Knowledge

Constraint knowledge is used to help define the acceptability of possible solutions to conflicts that exist between the current facility configuration and newly imposed functions on that facility. Individual pieces of constraint knowledge fall into one of three broad classifications: physical, safety or environmental. Each type of facility and their various functions involve a different set of constraint knowledge regarding facility modification.

Physical constraint knowledge for an MPRC includes the boundaries of the military installation and the range itself. Another physical constraint would be the minimum time between target exposures for each type of weapon system. A too rapid series of target exposures would not allow a weapon system or crew sufficient time to reload and engage the second target.

An example of a safety based constraint would be that no target may by exposed such that one weapon system firing at it could hit another weapon system or the calculated impact point would fall outside the designated impact area. Environmental contraints for an MPRC include no allowable increase in the size of the current impact area. This is a stated Army objective and is intended to end the growth of military installation property contaminated with shrapnel and possible unexploded ammunition.

4.5.4 Facility Modification Rules and Heuristics

Facility modification rules and heuristics differ from constraint knowledge in that they are used to efficiently guide the search process needed to find solutions to the previously identified conflicts. These rules and heuristics are primarily concerned with facility design, modification and operation restrictions and considerations. Examples of MPRC modification rules and heuristics are listed below:

- Gun-target engagement sequences begin at the range baseline and progess downrange during offensive training.

- Gun-target engagement sequences begin downrange and progress toward the range baseline during defensive training.

- Reversals in direction are not allowed.

- Weapon systems fire from maneuver lane centerline or from designated defilade positions.

- Individual weapon systems remain on single maneuver lane during each firing sequence.

- Multiple weapon system sequences keep all weapons progressing at the same speed.

- Intervisibility is required between before firing.

- Weapon system main gun engages armored vehicle targets.

- Other than main gun engages non-armored and personnel targets.

- Surface danger zone equals calculated impact area plus ammunition bursting radius times factor of safety.

CHAPTER 5 SYSTEM DESIGN AND OPERATION

5.1 Objectives

This facility modification methodology was developed as a general approach to a broad class of problems. It was intended to be applicable to a wide variety of facility types and configurations. The specific military training range application was chosen to illustrate the operation and features of the process. Geographic information system technology was selected for use in this application because of the nature of the data needed to represent and resolve the conflicts. Less terrain intensive facility modification problems would utilize other and more appropriate means to record, manipulate and display necessary information.

The methodology was developed with two objectives in mind. The general theme behind both objectives was to provide intelligent advice to decision makers and designers concerning the impacts of changes in technologies or the utilization of those technologies on existing facilities.

One objective was aimed at high level decision makers who examine various alternative configurations for the implementation of new technologies. In the case of U.S. Army training ranges and the multi-purpose range complex, this would equate to the weapons development sections of the Army Materiel Command as well as the doctrine and training strategy developers at TRADOC and DAART. Comprehensive analysis of the relative impacts caused by alternative configurations and doctrine has been lacking for the decision makers at these types of organizations.[1] This methodology was designed to allow the rapid and accurate evaluation of these impacts at a level of detail sufficient for these decisions.

The second objective was intended to assist designers and engineers at lower organizational levels. These are the people who are responsible for evaluating what facility modifications, if any, are required and how to best make those changes. In the case of the MPRC, these individuals are the installation commanders and their facility engineers. Once the physical and performance characteristics plus the new training requirements are finalized they must ensure that the existing training facilities will be adequate to accommodate the new weapon systems when they arrive or when new training standards and procedures go into effect. At this level, the nature of the facility modification advice is much more detailed and is intended to assist in the selection of the most appropriate corrective actions necessary to eliminate individual conflicts between the new requirements and the existing facility configuration.

5.2 MPRC Design Modification Process

The MPRC design modification process can be

[1] Howard Blood, telephone interview held with the program manager, Army Range Program, Huntsville, Alabama, April 1987.

represented as shown in figure 5.1. Problem solution or conflict resolution is reached by moving through a series of states. The problem's initial or start state is achieved by the recording of the existing facility configuration, the new requirement or function that the facility is being asked to accommodate plus the constraints that govern the facility's design and operation.

A representation of an MPRC training facility using a hierarchical semantic network is shown in figure 5.2. Figure 5.3 is a similar representation of the training functions for an MPRC.

Intermediate states are reached by a process of function matching aimed at identifying facility-function conflicts and their causes. Object oriented programming techniques are utilized to manipulate the knowledge from the initial state plus general problem solving knowledge and algorithms.

Constraint relaxation rules and heuristics are combined with facility modification cost data to provide users with recommended conflict resolution strategies. The goal state is reached by repeating the function matching, conflict identification and constraint relaxation processes until the facility modifications selected allow the new function(s) to be fully accommodated.

5.3 Operational Characteristics

The key element of the initial system imput for MPRC modification is the unconstrained gun-target engagement sequences or task listings. A varying number of these

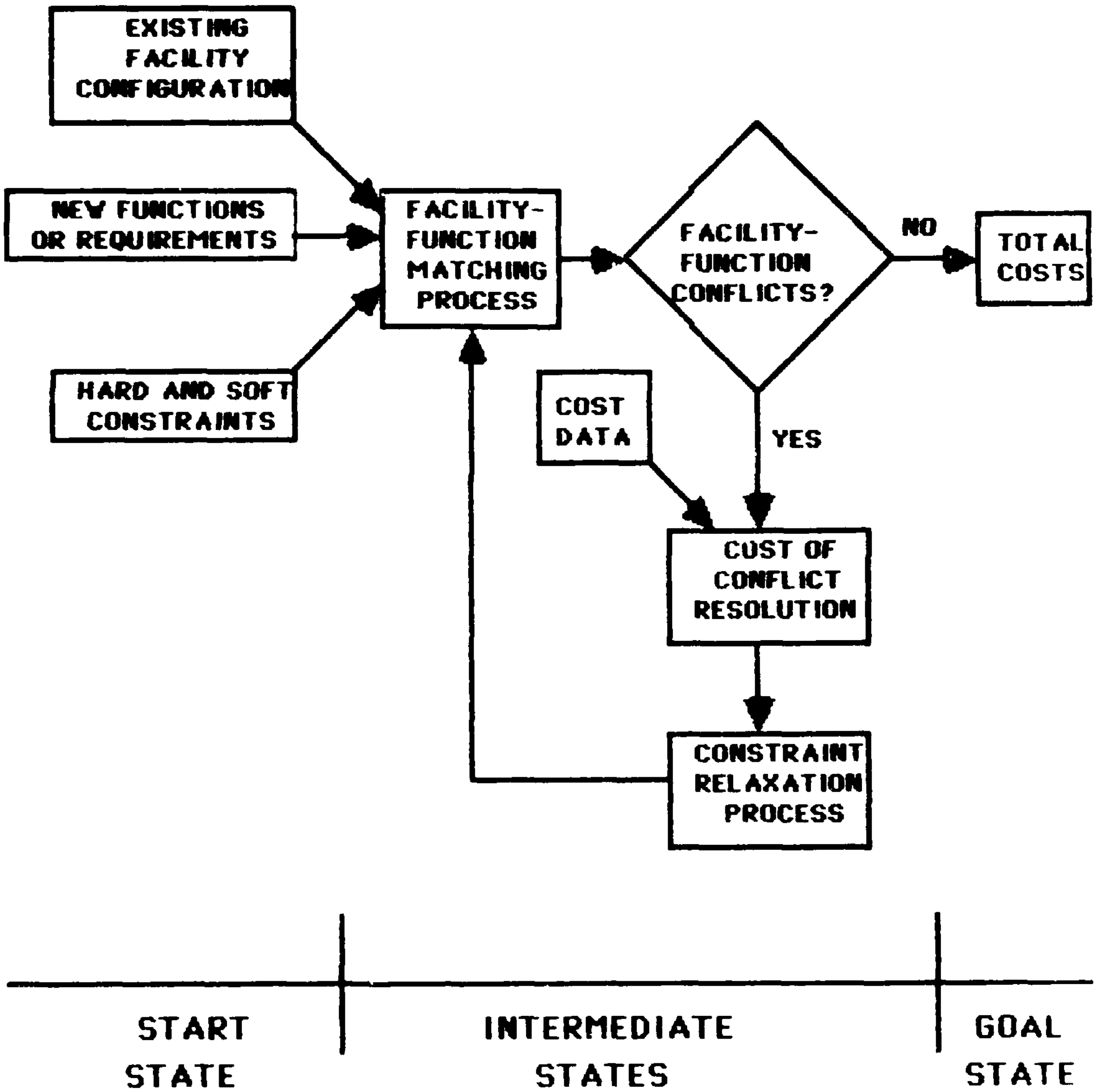

FIGURE 5.1 FACILITY MODIFICATION PROCESS

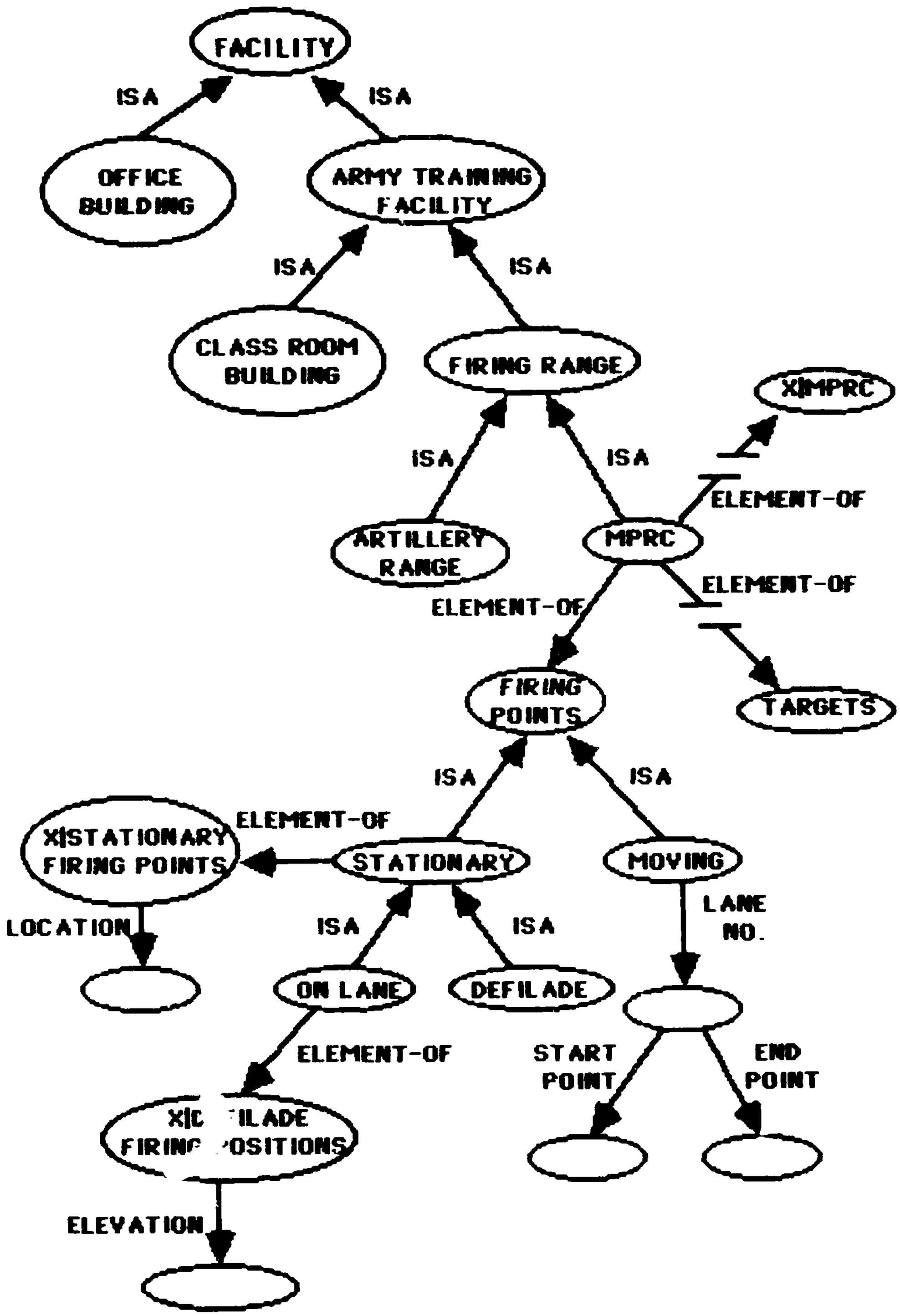

FIGURE 5.2 MULTI-PURPOSE RANGE COMPLEX REPRESENTATION AS A HIERARCHICAL SEMANTIC NETWORK

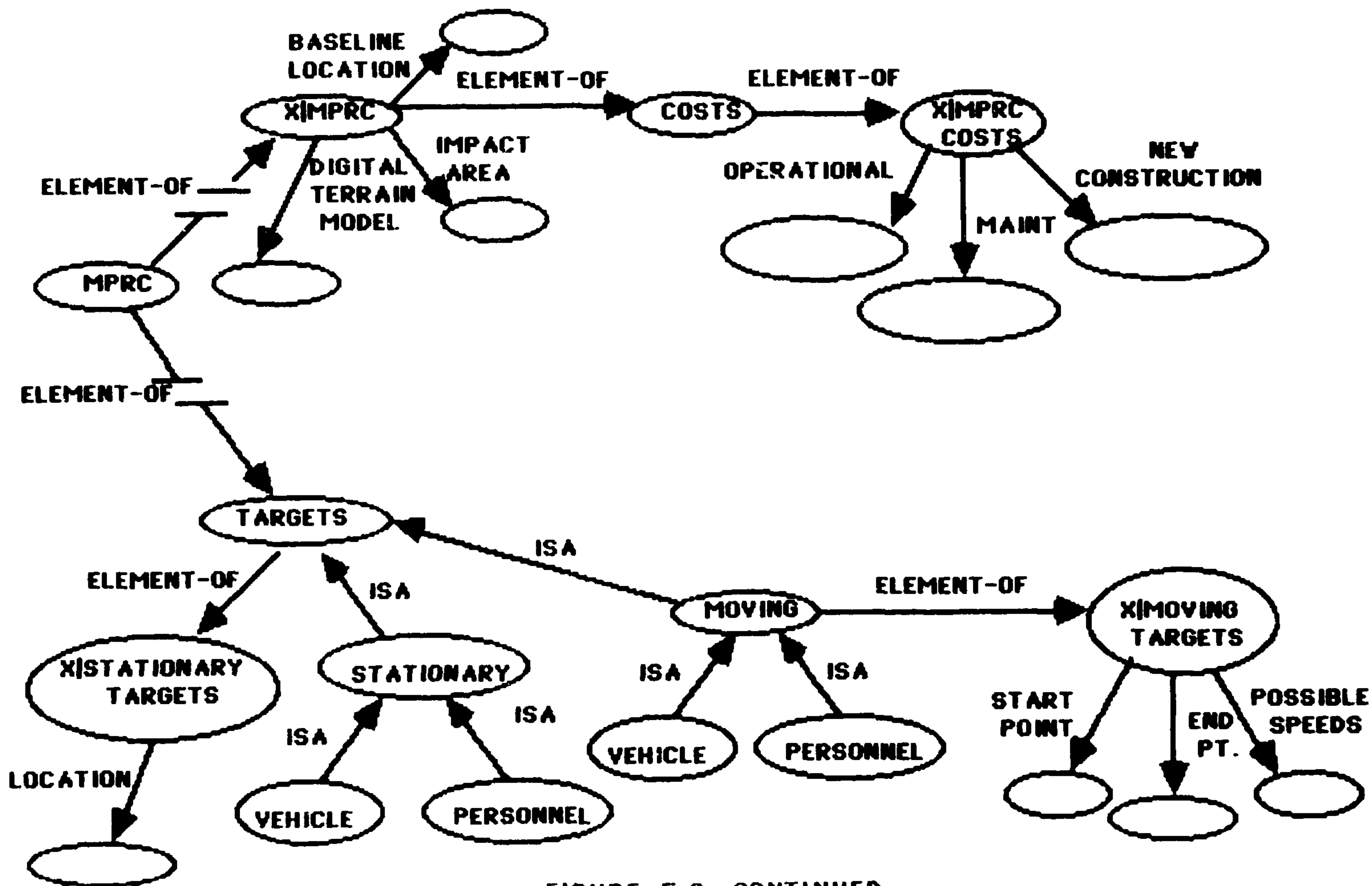

FIGURE 5.2 CONTINUED

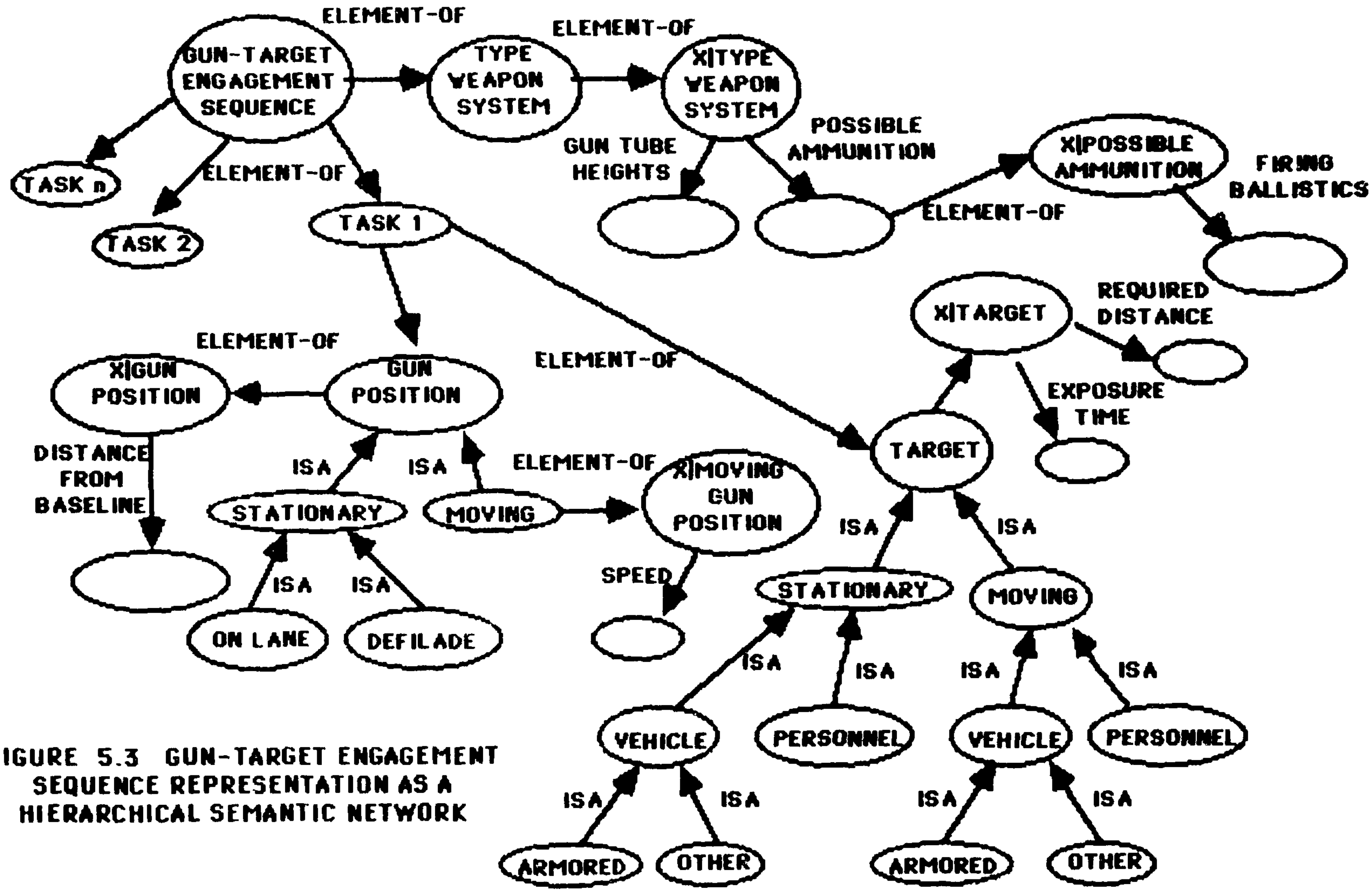

FIGURE 5.3 GUN-TARGET ENGAGEMENT SEQUENCE REPRESENTATION AS A HIERARCHICAL SEMANTIC NETWORK

sequences are used to define the periodic crew qualification requirements for each different type of weapon system. After these requirements are entered, the system's evaluation process searches for combinations of firing points, targets and interlying terrain that will satisfy the individual engagement requirements of the target type, distance and exposure time that require no facility modification.

In the event that no conflicts exist for any given gun-target exposure sequence, the system offers to provide the installation level user with one or more of the target exposure data sets needed to program the MPRC's operating and scoring computer.

When conflicts are detected, they are listed by classification, cause and estimated cost for correction. Possible causes of these conflicts include lack of intervisibility for required target exposure time, insufficient distance between target and firing point, calculated impact point violating designated surface danger zone and possible danger to other weapon systems operating on the facility.

The installation level user is provided with cost information on the possible conflict resolution strategies and is given the opportunity to relax previously specified constraints and goals. The search process for possible means to resolve the conflicts is lead by rules and heuristics regarding the physical, safety and environmental design and operation of the facility.

After the installation level user specifies the corrective action desired the process is repeated to evaluate for new conflicts that may have resulted. Once all conflicts have been resolved, the system then offers to provide the user with a number of possible target exposure data sets.

At the higher level of operation, this process provides advice to users who are concerned with materiel and doctrine development. For AMC's project managers plus officials at TRADOC and DAART the output consists of more generalized conflict listings and causes. These conflict causes can now include weapon system configuration and doctrinal features that may be altered at this stage of development. Constraint relaxation intended to resolve or reduce the facility-function conflicts can now include the physical configuration of the weapon system under development.

5.4 Computer Implementation and Case Study

A computer implementation of this facility modification methodology will utilize USA-CERL's GRASS geographic information system and its existing library of program development tools. This system runs under the UNIX operating environment, is written in the C programming language and utilizes either MASSCOMP or SUN workstations.

A case study using the Fort Riley, Kansas multipurpose range complex data file and digitized terrain model will be conducted to demonstrate the usefulness of the procedures developed and as a proof of concept. System development advice and funds for GRASS-GIS programming assistance will be provided by the U.S. Army Construction Engineering Research Laboratory.

Sources for knowledge acquisition needed for implementation will include TRADOC/DAART, OCE's Huntsville Division, USA-CERL's environmental and facilities divisions, and the U.S. Army armor and infantry branch schools at Fort Knox, Kentucky and Fort Benning, Georgia, respectively.

The goals of the case study are to show the methodology's ability to provide useful advice to both the weapon system and doctrine development process and to the individual installation facility modification process.

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